A DYNAMIC MODEL OF COCAINE PREVALENCE

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Summary

A system dynamics model reproduces a variety of national indicator data reflecting cocaine use and supply in the United States over a 15–20 year period and provides detailed estimates of actual underlying prevalence. The model's behavior is largely the consequence of its self-propelling feedback structure and therefore requires relatively few assumptions about changes in model inputs over time. Simulation results clarify and help to explain historical trends, such as growth in the compulsive use of crack cocaine, and decline in the casual use of cocaine powder. The model also points to a large gap between reported and actual prevalence, and shows how and why this gap developed. Alternative scenarios with possible policy implications are simulated, and projected several years into the future, and the results are assessed.

1. Background

The epidemic of cocaine use in the United States has proven consistently difficult to estimate and project forward in time. Self-report surveys inevitably suffer from biases related to partial coverage and inaccurate reporting, which make them unreliable as stand-alone tools for point estimation. Such surveys are suspect even as tools for trend or slope estimation, because the biases themselves are subject to change. For example, it seems likely that reporting of cocaine use has become less accurate over the last several years as the legal and social risks of such use have increased. Due to the inherent drawbacks of self-report surveys for estimating illicit drug use, researchers have often brought other indicators into play as well, such as data on drug-related morbidity and mortality, arrests and drug seizures, and price and purity. Although any single indicator provides only a partial, often indirect, view of the situation, the hope exists that taken together they may lead to more reliable estimates and projections.

Regardless of the specific approach taken, the synthesis of multiple indicators for making inferences about prevalence requires some sort of modeling of cause-and-effect relationships. This article starts from the premise that decision-makers confronted by a phenomenon as dynamically complex as illicit drug use should have available formal models, which are not only unambiguous and reliable, but also as realistic in detail and at least as broad in scope as their own mental models. It is this premise that led to the development of the system dynamics simulation model presented here.

The model was developed for the purpose of generating national cocaine prevalence estimates and projections consistent with available indicator data and knowledge of underlying processes. Its development from 1987 to 1990 was funded by the National Institute of Justice (NIJ), the research arm of the U.S. Department of Justice, and was done in collaboration with a university-based team of drug abuse researchers and statisticians. During the three-year period of development, various causal hypotheses were translated into equations, and these equations were tested to determine whether they were capable of reproducing historical data and of doing so with plausible parameter values. Through this process of model testing and evaluation, a number of hypotheses were rejected and others were refined. In line with system dynamics modeling principles, emphasis was placed on explaining trends as largely the result of endogenous feedback relationships rather than exogenous factors, and on restricting the number of such relationships so that the model would be manageable, understandable, and useful to decision-makers.

2. Data Sources and Trends 1976–1990

A variety of national indicator data helped to enrich and calibrate the model's structure and helped to reduce the degree of uncertainty in model assumptions and estimates. The key longitudinal data used for these purposes, drawn from various governmental publications and databases and covering the 1976–1990 period, are presented in Table 1. They include self-reported use data from the National Household Survey (NHS), the High School Senior Survey (HSSS), and the Drug Use Forecasting (DUF) project, morbidity, and mortality data from the Drug Abuse Warning Network (DAWN), arrest and incarceration data from the Uniform Crime Reports (UCR), and the Offender-Based Transaction Statistics (OBTS), and data on drug seizure volumes, price, and purity from the Drug Enforcement Administration's (DEA) NNICC Reports and STRIDE database.

National Household Survey (NHS) from National Institute on Drug Abuse (NIDA), reports for 1976, 1977, 1979, 1982, 1985, 1988, and 1990 (also, 1993, 1995):

- Past month, past year, and lifetime use of cocaine and marijuana.
- Past month, past year, and lifetime use of crack (recorded starting 1988).
- Weekly use of cocaine (recorded starting 1985).

High School Senior Survey (HSSS) from NIDA, annual reports 1976–1990 (also, 1991–1995):
- Past month, past year, and lifetime use of cocaine, marijuana, and "any illicit drug."
- Past month, past year, and lifetime use of crack (recorded starting 1987).
- Attitudes, beliefs, and social milieu for cocaine.

Drug Abuse Warning Network (DAWN) from NIDA, annual and semiannual reports 1976–1990 (also, annual reports 1991–1995):
- Emergency room mentions of cocaine, totals reported by quarter (1990 disregarded due to apparent sampling anomalies).
- Medical examiner mentions of cocaine.

Drug Use Forecasting (DUF) project from National Institute of Justice (NIJ), quarterly interview database 1988–1989:
- Past day and past month use of cocaine powder and crack.

Uniform Crime Reports (UCR) from Federal Bureau of Investigation (FBI), quarterly reports 1977-1989 and annual report 1990 (also, annual reports 1991–1995):
- Felony arrests for cocaine and opiate possession and sales/manufacture.

Offender-Based Transaction Statistics (OBTS) from Bureau of Justice Statistics (BJS), annual reports 1983-1987:
- Incarceration rates for state drug-law felony arrests.

National Narcotics Intelligence Consumers Committee (NNICC) Reports from Drug Enforcement Administration (DEA), annual reports 1977–1989:
- Federal seizures of cocaine.

System to Retrieve Drug Evidence (STRIDE) from DEA, continuous seizure database 1977–1990:
- Price, purity, and quantity per cocaine seizure.

Table 1. National indicator data for modeling cocaine prevalence.

Some of the salient trends observed in these indicator data are presented in Figures 1 through 5. Figure 1 shows how, for both the general population (NHS) and high school seniors (HSSS), self-reported past month cocaine use prevalence grew rapidly in the late 1970s, was relatively stable during the early 1980s, and then fell rapidly in the late 1980s. Self-reported past month marijuana use, graphed in Figure 2, also displays a rise-and-fall pattern, but the timing and magnitude are clearly different than cocaine's: the marijuana figures grow only modestly in the late 1970s, then decline throughout both the early and the late 1980s. The HSSS also tracks self-reported use of "any illicit drug," which shows a pattern nearly identical to that for marijuana use. One may conclude that self-reported cocaine use has not simply tracked illicit drug use in general, but has followed its own unique path.

Figures 3 and 4 present time series on the negative consequences of cocaine use: Figure 3 presents DAWN data on emergency room (ER) and medical examiner (ME) mentions, while Figure 4 presents UCR data on drug-law felony arrests for cocaine and opiates. These time series all display a general pattern of little or no growth in the late 1970s, followed by rapid growth in the 1980s through 1988 or 1989. These indicators clearly suggest enormous growth in the negative consequences of cocaine use during just those years when self-reported past month use was increasing little or was on the decline. Similar growth during the 1980s is also seen in data on drug-felony incarceration rates and cocaine seizures.

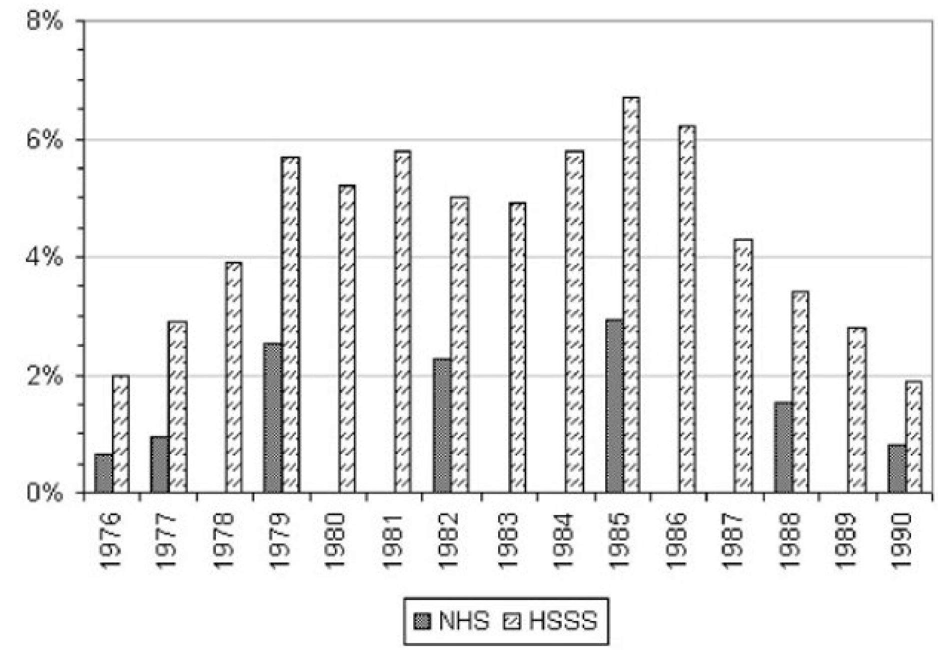

Figure 1. Past month cocaine use self-report fractions from NHS and HSSS.

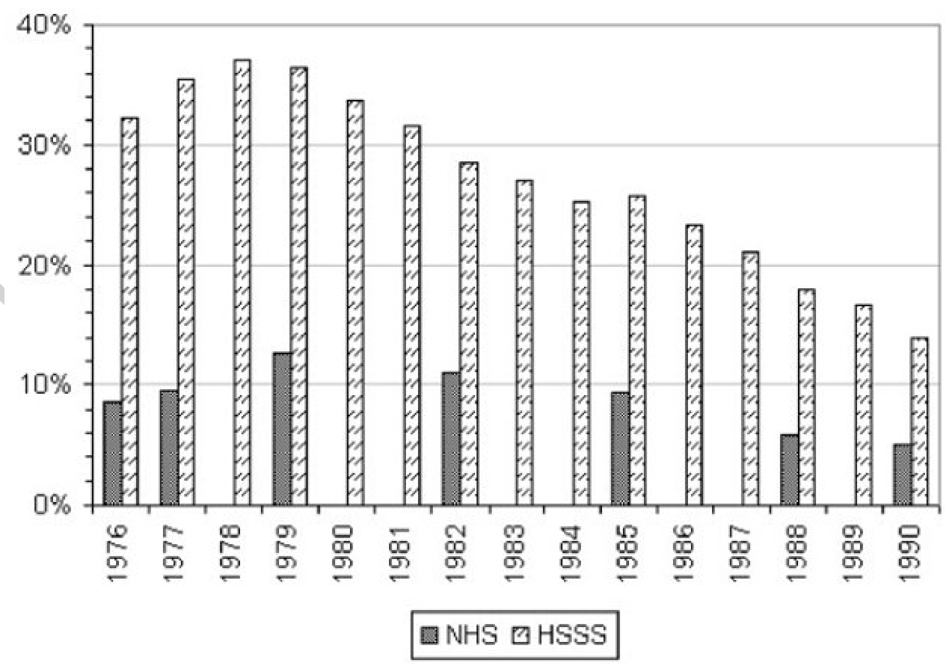

Figure 2. Past month marijuana use self-report fractions from NHS and HSSS.

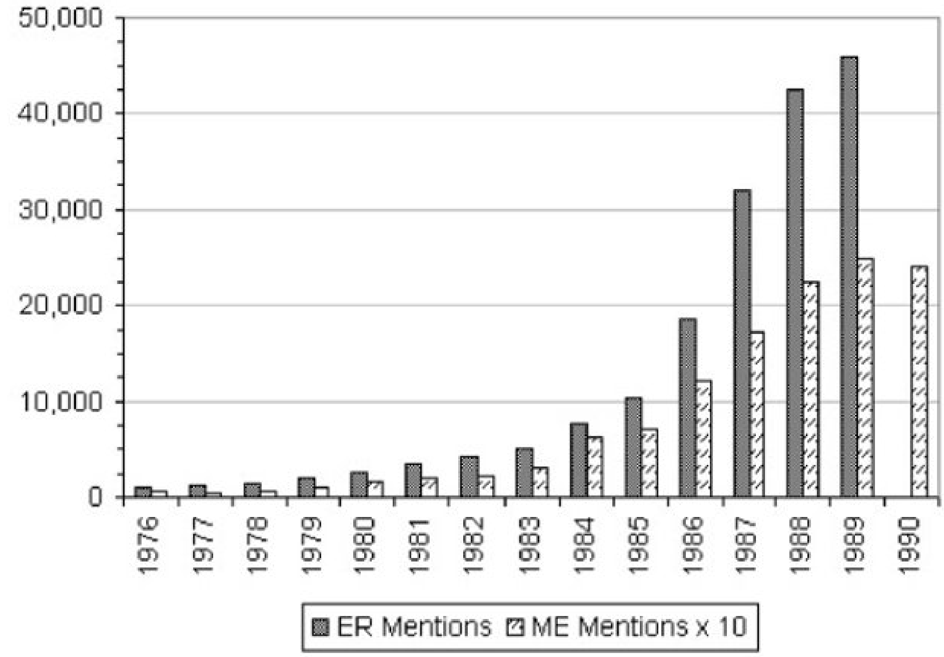

Figure 3. Emergency room and medical examiner cocaine mentions from DAWN.

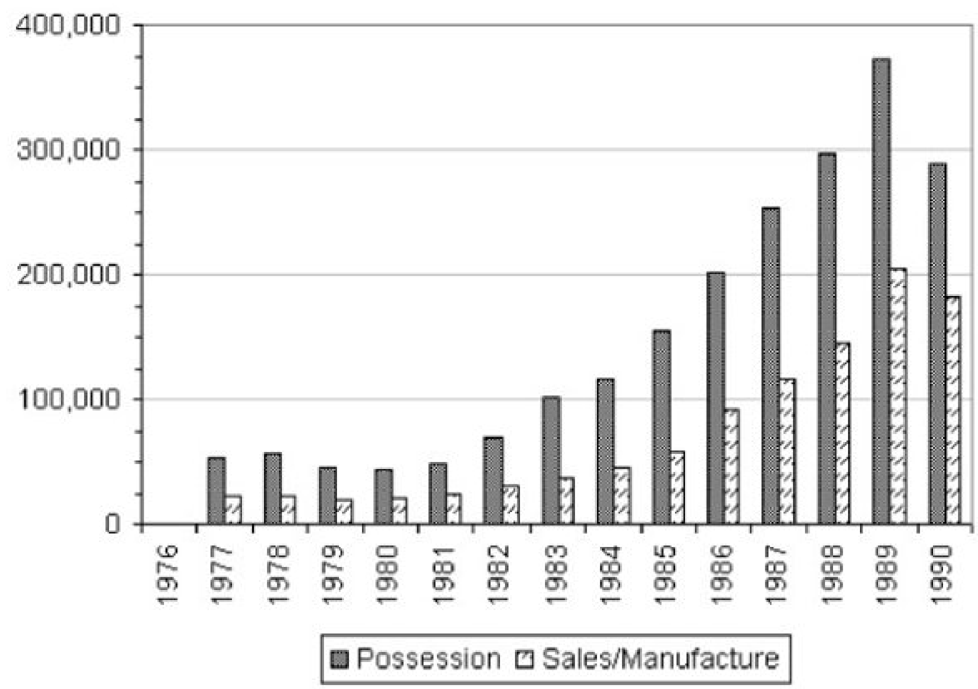

Figure 4. Felony arrests for cocaine/opiate possession and sales/manufacture from UCR.

Growth in cocaine consequences and the cocaine trade during the 1980s coincided with the spread of crack cocaine. Crack, an easily processed, easily transported, and smokeable, and highly addictive form of cocaine, was first reported in Southern California and Texas in 1981, spread to New York City in 1984, and was found in urban areas all over the country by 1986. Cocaine ER mentions attributed to smoking the drug grew from two percent of all cocaine ER mentions in 1983 to 37% in 1989, while ER mentions attributed to sniffing or injection declined from 86% to 35% of the total. By 1987, and through 1990, crack accounted for thirty-five to fifty percent of self-reported past month use of cocaine, according to HSSS and DUF.

A factor, which undoubtedly helped to fuel the growth in cocaine powder use during the late 1970s, and crack use during the 1980s, is the substantial decline in the price of cocaine throughout this period. Figure 5 presents estimates calculated from STRIDE seizure data on the average retail price (in 1990 US dollars) per gram, expressed in terms of both adulterated and pure quantities. The decline in price is evident in both measures, but most dramatic for price per pure gram, the measure, which more accurately describes the cost for a given amount of drug effect; price per pure gram fell from about US$600 in the late 1970s, to about US$300 in the early 1980s, to less than US$200 in the late 1980s. This decline in price was concurrent with an increase in average retail purity, which grew from less than 40% in the late 1970s, to about 50% in the early 1980s, to over 70% in the late 1980s. These long-running trends continued until 1990, a year of relative shortage in which price increased and purity decreased moderately.

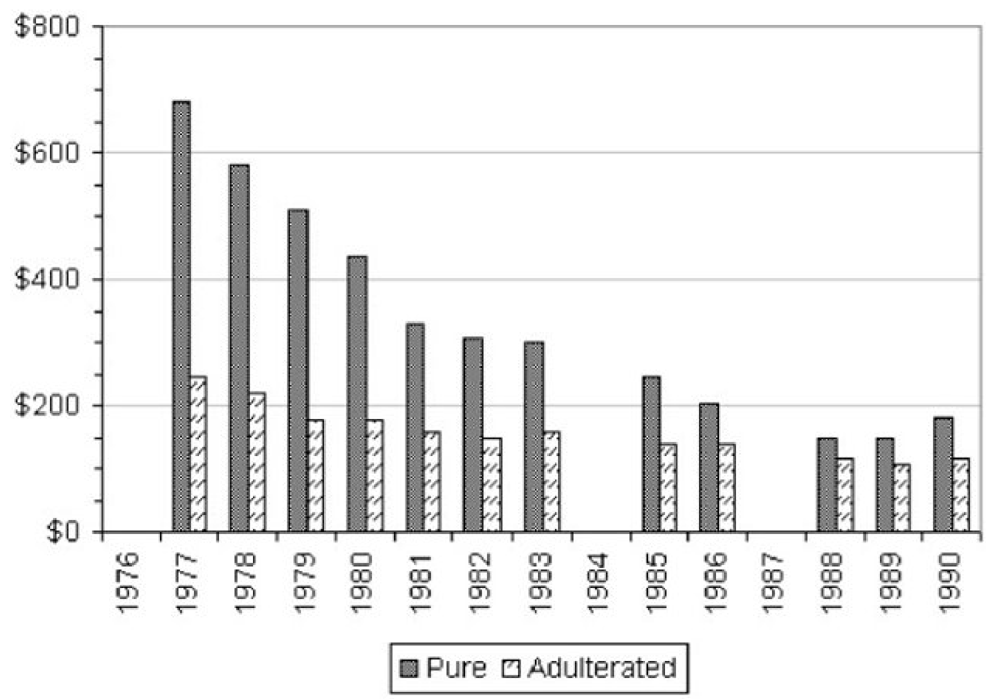

Figure 5. Retail price per gram of cocaine (in 1990 US dollars) from STRIDE.

Other trends worthy of mention are those reflected in the HSSS data on cocaine-related attitudes, beliefs, and social milieu. In regard to attitudes and beliefs, these data show that the fraction of high school seniors and young adults perceiving cocaine as a major health risk increased steadily throughout the 1980s, with the biggest changes in perception occurring prior to 1988. In regard to social milieu, the fraction of respondents who report having observed cocaine use during the past year, or having friends who use cocaine, followed a rise-and-fall pattern from 1976 to 1990, looking similar to the HSSS data on cocaine prevalence itself, as one might expect.

3. Model Structure and Parameters

3.1 Model Overview

An overview of the model's cause-and-effect structure is diagrammed in Figure 6. The entire indicator variables discussed in the preceding section is included in this structure, as well as those "hidden" variables, which lie behind the indicators.

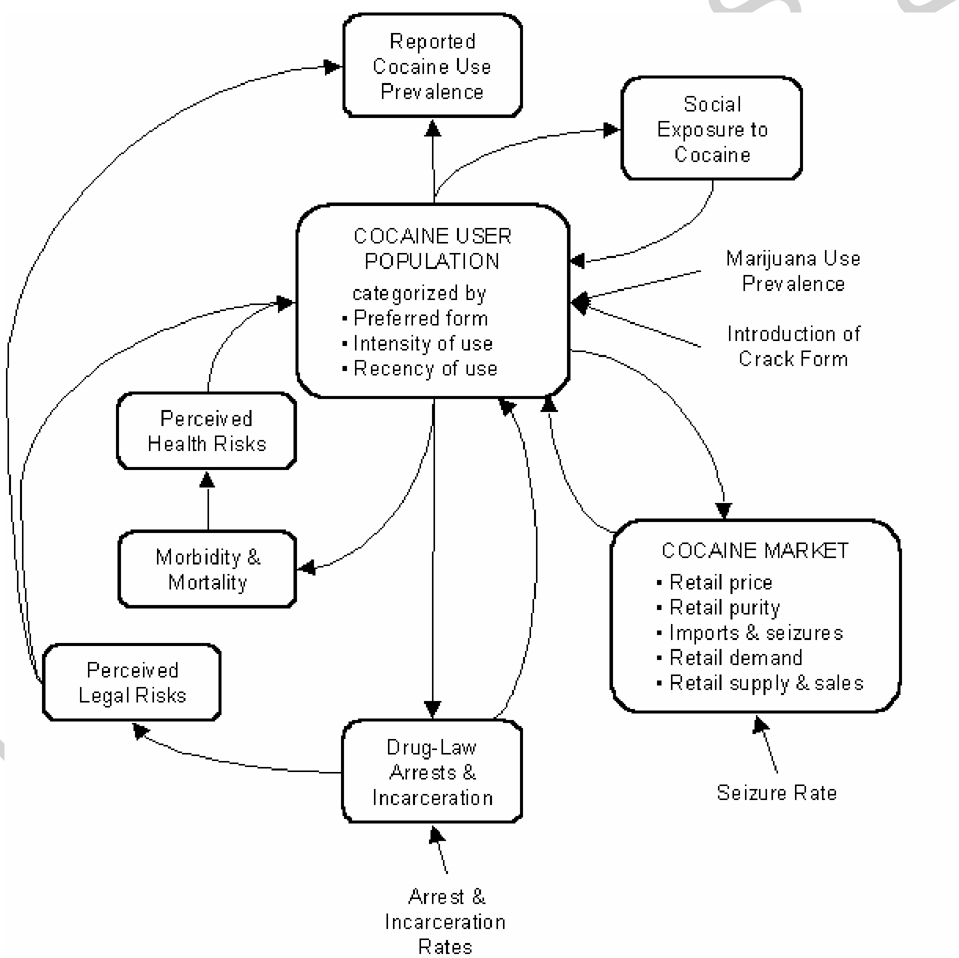

Figure 6. Overview of model structure.

For example, reported cocaine use prevalence (expressed, as in the NHS, in terms of past-month, past-year, and lifetime use) is computed in the model by starting from the underlying (hidden) actual user population and applying reporting rates which are themselves subject to change. Similarly, price, purity, and seizure indicators change over time in response to such hidden market variables as imports and consumption. By following the arrows in Figure 6, one may see that most of the model's variables interact with one another, being elements of feedback loops rather than pure inputs or pure outputs. In particular, the consequences of cocaine use—such as morbidity, arrests, and effects on price—feed back to affect future use. However, the model does contain a small number of important exogenous variables, which also have a role in determining model behavior. These include marijuana use prevalence, arrest and incarceration rates, and the rate at which imports are seized.

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Biographical Sketch

Dr. Jack B. Homer is a system dynamics modeling consultant with clients in business and government and has directed Homer Consulting since 1989. In the public sector, he works and writes on health-related issues, including drug abuse, infectious disease, and medical technology diffusion, and has developed models for the National Institute of Justice, the National Institutes of Health, and the Texas Department of Health. He was formerly an assistant professor at the University of Southern California, where he directed the System Dynamics Laboratory and organized the 1988 International System Dynamics Conference. He holds a Ph.D. degree in management from M.I.T., and bachelors and master's degrees in applied mathematics and statistics from Stanford University. In 1997, he received the Jay W. Forrester Award from the System Dynamics Society for best contribution to the field in the preceding five years, in recognition of his work on the dynamics of cocaine prevalence.